

THE ACOUSTIC REALIZATION OF SCHWA IN UNSTRESSED SYLLABLES OF BRITISH ENGLISH

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Abstract: Schwa /ə/ is one of the most frequent vowel sounds in English and is strongly associated with unstressed syllables and processes of vowel reduction. Although schwa is traditionally described as a central and relatively neutral vowel, its actual acoustic realization may vary according to phonetic context, syllable position, speech rate, and neighbouring segments. This study investigates the acoustic realization of schwa in unstressed syllables of British English using speech material from the spoken component of the International Corpus of English-Great Britain (ICE-GB). The analysis focuses on three principal acoustic parameters: first-formant frequency (F1), second-formant frequency (F2), and vowel duration. Candidate schwa tokens were identified from the corpus transcripts and examined acoustically using waveform and spectrographic information. An initial set of 59 acoustic candidate observations was subjected to an acoustic quality-screening procedure, resulting in 39 observations retained for descriptive analysis. The screened observations yielded a mean F1 of 462.32 Hz (SD = 79.93), a mean F2 of 1482.06 Hz (SD = 235.49), and a mean duration of 83.59 ms (SD = 41.66). Exploratory statistical comparisons across lexical target groups did not reveal statistically significant differences in F1, F2, or duration. However, the observed dispersion of the acoustic measurements indicates that schwa is not represented by a single acoustically invariant configuration. The findings are discussed in relation to previous acoustic descriptions of schwa, particularly the work of Kondo and Bates, and support an interpretation of schwa as a phonological category whose phonetic realization is sensitive to its surrounding context.

Keywords: British English, schwa, vowel reduction, acoustic phonetics, unstressed syllables, F1, F2, vowel duration, phonetic context, coarticulation

1. Introduction

Vowel reduction is one of the characteristic features of English pronunciation and plays an important role in the organization of unstressed syllables [1]. In contrast to stressed vowels, which generally preserve relatively clear segmental and acoustic characteristics, vowels in unstressed positions may undergo reduction in duration, spectral differentiation, and articulatory precision. Among the vowels associated with

reduction, schwa /ə/ occupies a particularly important position because it occurs extensively in unstressed syllables in both conversational and read speech.

Schwa is traditionally characterized as a mid-central vowel and is frequently represented as the prototypical reduced vowel in English [2,3]. In phonological descriptions, it is associated primarily with unstressed syllables and may occur in a wide range of grammatical and lexical environments. Examples include the initial syllables of *about* /ə'baʊt/, *ago* /ə'gəʊ/, and *around* /ə'raʊnd/, as well as the first vowel of *police* /pə'li:s/. Its high frequency and strong association with unstressed syllables make schwa an important subject for research into the relationship between phonological representation and actual speech production.

The description of schwa as a central or neutral vowel, however, does not necessarily imply that all occurrences of schwa have identical acoustic properties. Acoustic studies have demonstrated that the realization of reduced vowels may depend on their surrounding phonetic environment [4]. In particular, the frequencies of the first and second formants may be influenced by neighbouring consonants and vowels, while vowel duration may vary according to prosodic and segmental conditions. Thus, the phonological category /ə/ may correspond to a range of phonetic realizations rather than to a single fixed acoustic target.

One important question concerns the relationship between the abstract representation of schwa and its observable acoustic properties. If schwa were acoustically invariant, its F1, F2, and duration values would be expected to cluster relatively closely around a stable target. If, on the other hand, schwa is substantially affected by its phonetic environment, greater acoustic dispersion should be observed. This issue is particularly relevant to British English, where reduction and connected-speech processes contribute significantly to vowel realization.

Previous research provides evidence for contextual variability. Kondo's acoustic investigation of British English schwa demonstrated systematic effects of both vocalic and consonantal context on its acoustic realization, with particularly substantial variation in F2 [4]. Bates likewise reported extensive variability in reduced vowels in connected speech and emphasized the context-dependent nature of schwa [5]. These studies suggest that the traditional description of schwa as a neutral central vowel requires consideration of the phonetic environment in which it occurs.

The present study examines this issue using authentic British English speech material from the International Corpus of English-Great Britain. Rather than treating schwa exclusively as an abstract phonological category, the study considers its measurable acoustic properties in naturally occurring corpus speech. Three parameters are examined: F1, F2, and vowel duration. These parameters provide complementary information about vowel quality and temporal reduction.

The study addresses three research questions. First, what are the characteristic F1 and F2 patterns observed in schwa tokens occurring in unstressed syllables of British English? Second, how does the duration of schwa vary across the examined corpus tokens? Third, to what extent does the acoustic realization of schwa demonstrate contextual variability?

The purpose of the study is therefore not simply to establish a numerical average for schwa, but to investigate whether a single acoustic description adequately represents its realization in British English speech. By combining corpus-based speech material with acoustic analysis, the study contributes to the empirical description of vowel reduction and provides further evidence concerning the relationship between phonological reduction and phonetic realization.

2. Theoretical Background and Previous Research

2.1. Schwa and vowel reduction

Schwa is conventionally associated with unstressed syllables and vowel reduction. In English, stress plays a central role in determining the degree to which vowel quality and duration are preserved. Stressed vowels generally exhibit greater articulatory prominence and more differentiated formant structures, whereas unstressed vowels may become shorter and less spectrally distinct.

The phonological representation /ə/ is particularly common in unstressed syllables. Words such as *about*, *ago*, *around*, *again*, *perhaps*, and *police* provide examples in which the reduced vowel occurs in different segmental environments. These environments are important because the vowel is produced in temporal proximity to different consonantal configurations.

The existence of schwa as a phonological category does not necessarily mean that its acoustic realization is uniform. The physical speech signal reflects articulatory transitions between neighbouring segments, and reduced vowels may therefore exhibit acoustic properties that differ according to context.

2.2. Acoustic characteristics of schwa

Formant frequencies are among the principal acoustic measures used in the investigation of vowel quality. F1 is commonly associated with the vertical dimension of vowel articulation, while F2 provides information related to the front-back dimension. Although the relationship between formant frequencies and articulation is not completely direct, F1 and F2 provide useful acoustic correlates for comparing vowel realizations.

For a traditionally defined central vowel, schwa might be expected to demonstrate intermediate F1 and F2 values. However, an acoustic target should not be interpreted as an absolute fixed point. Coarticulation, speech rate, prosodic structure, and neighbouring segments can alter the acoustic realization of a vowel.

Kondo's study is particularly relevant in this respect. Her analysis of British English schwa demonstrated that consonantal and vocalic contexts influenced the acoustic realization of the vowel. The effects were especially visible in F2, whereas F1 exhibited comparatively smaller variation. This observation led to an interpretation in which schwa may have a relatively stable height-related specification while remaining less precisely specified in the front-back dimension.

2.3. Duration and temporal reduction

Duration constitutes another important acoustic correlate of vowel reduction. Unstressed vowels are frequently shorter than their stressed counterparts, although duration depends on several factors, including speech rate, phrase position, syllable structure, and neighbouring consonants [6].

The temporal reduction of schwa is therefore not simply a consequence of its phonological identity. The duration of an individual token may also reflect local speech conditions. Consequently, the analysis of duration alongside F1 and F2 is necessary for a more comprehensive description of schwa.

2.4. Contextual variation and coarticulation

Speech production involves continuous articulatory movement rather than the production of completely independent segments. Coarticulation causes the acoustic properties of one segment to be influenced by adjacent segments. This is particularly important for short and unstressed vowels because there may be insufficient temporal space for the articulatory system to reach and maintain an idealized vowel target.

For schwa, contextual variation may therefore be reflected especially strongly in F2. A preceding or following consonant can influence the articulatory trajectory of the vowel, producing measurable differences in the acoustic signal.

This perspective is consistent with the concept of phonetic underspecification discussed by Kondo. Rather than assuming that schwa possesses a fully specified acoustic target equivalent to the targets of stressed vowels, the reduced vowel may be understood as a category whose phonetic realization is comparatively dependent on its environment.

2.5. Previous acoustic research

Bates conducted a detailed acoustic investigation of vowel reduction in English using a corpus of read sentences and examined thousands of vowel tokens. Her work emphasized the considerable variability of vowels in connected speech and showed that schwa is particularly sensitive to contextual factors [5].

Flemming and Johnson examined reduced vowels in American English and demonstrated that reduced vowel quality is systematically related to phonetic context [7]. Volín, Weingartová, and Skarnitzl likewise investigated the spectral characteristics of schwa and highlighted variation in its acoustic realization across phonetic environments [8]. Byers and Yavas further examined vowel reduction in relation to

adjacent consonantal contexts and reported effects in both the spectral and temporal dimensions of reduced vowels [9].

Kondo's work provides a complementary perspective by examining phonetic underspecification and the acoustic effects of context. The study demonstrated that F2 may vary substantially according to the consonantal and vocalic environment, whereas F1 may be comparatively stable [4].

Together, these studies provide an important theoretical basis for the present investigation. They suggest that the analysis of schwa should not be limited to a categorical description such as "central vowel." Instead, acoustic measurements should be used to examine the extent to which individual realizations vary.

2.6. Research gap

Although previous studies have established that schwa may exhibit contextual acoustic variability, corpus-based descriptive analyses remain useful for examining how this variability appears in authentic British English speech. The present study addresses this issue through an analysis of ICE-GB speech material, focusing specifically on F1, F2, and duration.

The study does not attempt to replace earlier experimental research. Instead, it provides a corpus-based acoustic perspective that connects phonological descriptions of vowel reduction with measurable properties of actual British English speech.

3. Materials and Methods

3.1. Speech material and corpus

The empirical material for the study was obtained from the spoken component of the International Corpus of English-Great Britain (ICE-GB) [10]. The corpus provides authentic British English speech accompanied by transcribed material, allowing potentially relevant lexical items containing unstressed schwa to be identified.

The analysis focused on words in which schwa occurs in an unstressed syllable. Representative target lexical items included *around*, *police*, *ago*, *about*, *perhaps*, and *again*, which provide naturally occurring examples of schwa in different phonetic environments. The examples presented in Table 1 are illustrative rather than exhaustive; the quantitative analysis was based on the broader set of acoustic candidate observations identified from the corpus material.

Table 1.

Representative schwa-bearing tokens identified in the ICE-GB speech material

No.	Target word	Phonetic form	Corpus text	Sentence
1	<i>around</i>	/ə'raʊnd/	S2B-016	5
2	<i>police</i>	/pə'li:s/	S2B-016	9
3	<i>ago</i>	/ə'gəʊ/	S2B-016	36
4	<i>about</i>	/ə'baʊt/	S2B-016	72
5	<i>perhaps</i>	/pə'hæps/	S2B-016	89

6	<i>about</i>	/ə'baʊt/	S2B-016	101
7	<i>again</i>	/ə'gen/	S2B-016	107
8	<i>about</i>	/ə'baʊt/	S2B-016	108
9	<i>ago</i>	/ə'gəʊ/	S2B-016	115

The table presents representative schwa-bearing tokens identified in the corpus material. It does not represent the complete set of 59 initial acoustic candidate observations used in the subsequent screening procedure.

3.2. Identification and acoustic analysis

The target tokens were first identified through the corpus transcripts. The corresponding speech recordings were then examined acoustically. The analysis used waveform and spectrographic information to identify candidate intervals corresponding to the reduced vowel.

Praat was used as the principal acoustic analysis environment [11]. For each candidate token, the analysis focused on the vowel interval and extracted three acoustic parameters: first-formant frequency (F1), second-formant frequency (F2), and vowel duration.

F1 and F2 were treated as indicators of the spectral characteristics of the vowel, while duration was used to characterize its temporal realization. The combined analysis of these parameters was intended to provide a multidimensional description of schwa rather than relying on a single acoustic measurement.



Figure 1. Overall workflow of the corpus-based acoustic analysis

3.3. Acoustic quality screening

The initial extraction produced 59 candidate acoustic observations. Because automatic or semi-automatic candidate extraction can include measurements affected by consonantal transitions, weak periodicity, spectral irregularities, or uncertain vowel boundaries, a quality-screening procedure was applied.

The screening procedure retained observations with acoustically plausible F1, F2, and duration values for the present descriptive analysis. Measurements affected by uncertain vowel boundaries, strong consonantal transitions, weak periodicity, or unstable formant tracking were excluded from the final descriptive dataset. These 39 observations constitute the quantitative dataset reported in the Results section.

The screening procedure should be understood as a quality-control step rather than as a claim that the excluded observations are linguistically impossible schwa realizations. In particular, acoustic measurements near consonantal transitions may be difficult to interpret as stable vowel measurements. Therefore, the final descriptive

statistics are based on the subset for which the acoustic measurements were considered sufficiently reliable.

3.4. Statistical analysis

Descriptive statistics were calculated for F1, F2, and vowel duration. For each acoustic parameter, the mean, standard deviation, median, minimum, and maximum were calculated. Because the lexical target groups were relatively small and unevenly distributed, the Kruskal-Wallis test was treated as the primary non-parametric exploratory comparison. This test was used to examine whether the distributions of F1, F2, and duration differed systematically across the lexical target groups. One-way analysis of variance (ANOVA) was additionally calculated as a supplementary exploratory comparison of group means.

The statistical analysis was not intended to provide a definitive test of contextual effects in British English schwa. The lexical groups were not designed as balanced experimental conditions, and lexical identity is partly confounded with phonetic environment. Therefore, the statistical results are interpreted cautiously and are used primarily to characterize the present corpus sample rather than to generalize to the entire population of British English speakers.

4. Results

4.1. General acoustic characteristics

The acoustic analysis produced 59 initial candidate observations. Following quality screening, 39 observations were retained for the principal descriptive analysis. The resulting dataset provides measurements of F1, F2, and duration for schwa tokens occurring in unstressed syllables.

The mean F1 of the screened observations was 462.32 Hz, with a standard deviation of 79.93 Hz. The median F1 was 453.80 Hz, while the observed range extended from 329.2 to 642.1 Hz. These values indicate measurable variation in the first formant across the analyzed tokens.

The mean F2 was 1482.06 Hz, with a standard deviation of 235.49 Hz. The median F2 was 1456.80 Hz, and the observed values ranged from 902.4 to 1894.0 Hz. The relatively broad distribution of F2 is particularly relevant because F2 is sensitive to front-back positioning and may be affected by neighbouring segments.

The mean duration of the screened schwa observations was 83.59 ms, with a standard deviation of 41.66 ms. The median duration was 80.00 ms, and individual measurements ranged from 25 to 145 ms. The duration results therefore demonstrate considerable temporal variability within the analyzed sample.

Table 2.

Descriptive statistics of the screened schwa measurements

Acoustic parameter	N	Mean	SD	Median	Minimum	Maximum
F1 (Hz)	39	462.32	79.93	453.80	329.2	642.1

F2 (Hz)	39	1482.06	235.49	1456.80	902.4	1894.0
Duration (ms)	39	83.59	41.66	80.00	25.0	145.0

4.2. Acoustic realization in individual lexical items

The analyzed lexical items demonstrate that schwa occurs in several different phonetic configurations. For example, *about* and *ago* contain word-initial schwa followed by a stressed syllable, whereas *police* contains an unstressed schwa between an initial consonant and the stressed vowel /i:/. *Perhaps* provides another consonantly conditioned environment, while *around* and *again* provide additional examples of reduced-vowel realization before different stressed vowel configurations.

The presence of acoustic dispersion across these lexical environments indicates that schwa cannot be characterized solely by its phonological label. Even where the same phonemic category /ə/ is involved, the measured acoustic signal can differ according to the surrounding segments and the temporal organization of the word.

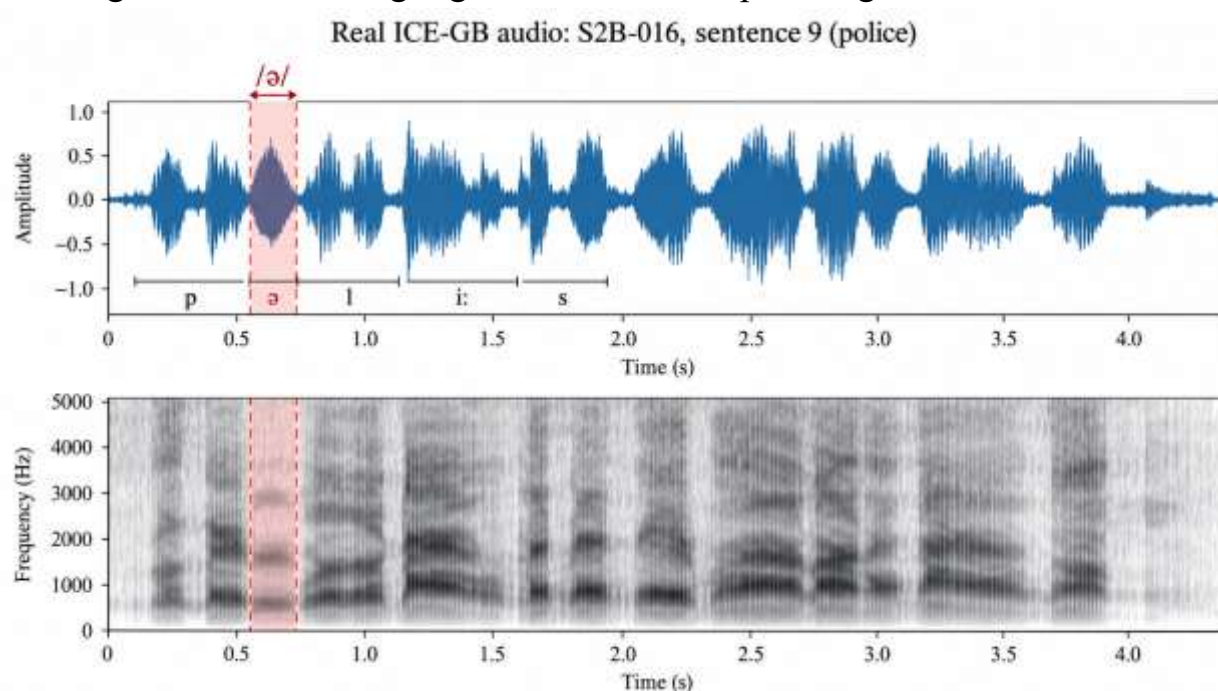


Figure 2. Example of acoustic analysis of schwa in the ICE-GB speech material

Waveform and spectrogram of the real ICE-GB recording for the target word *police* in S2B-016. The highlighted interval represents the candidate acoustic region used for measurement.

The waveform and spectrogram provide a visual representation of the acoustic structure of a real corpus token. The spectrographic representation also demonstrates why the identification of a reduced vowel should consider both temporal and spectral information rather than relying exclusively on orthographic transcription.

4.3. F1 and F2 distribution

The F1-F2 distribution provides an additional representation of the acoustic variability of the analyzed schwa tokens. The measurements occupy a relatively broad

region rather than forming a single point. This pattern is consistent with the expectation that reduced vowels are influenced by their surrounding phonetic environment.

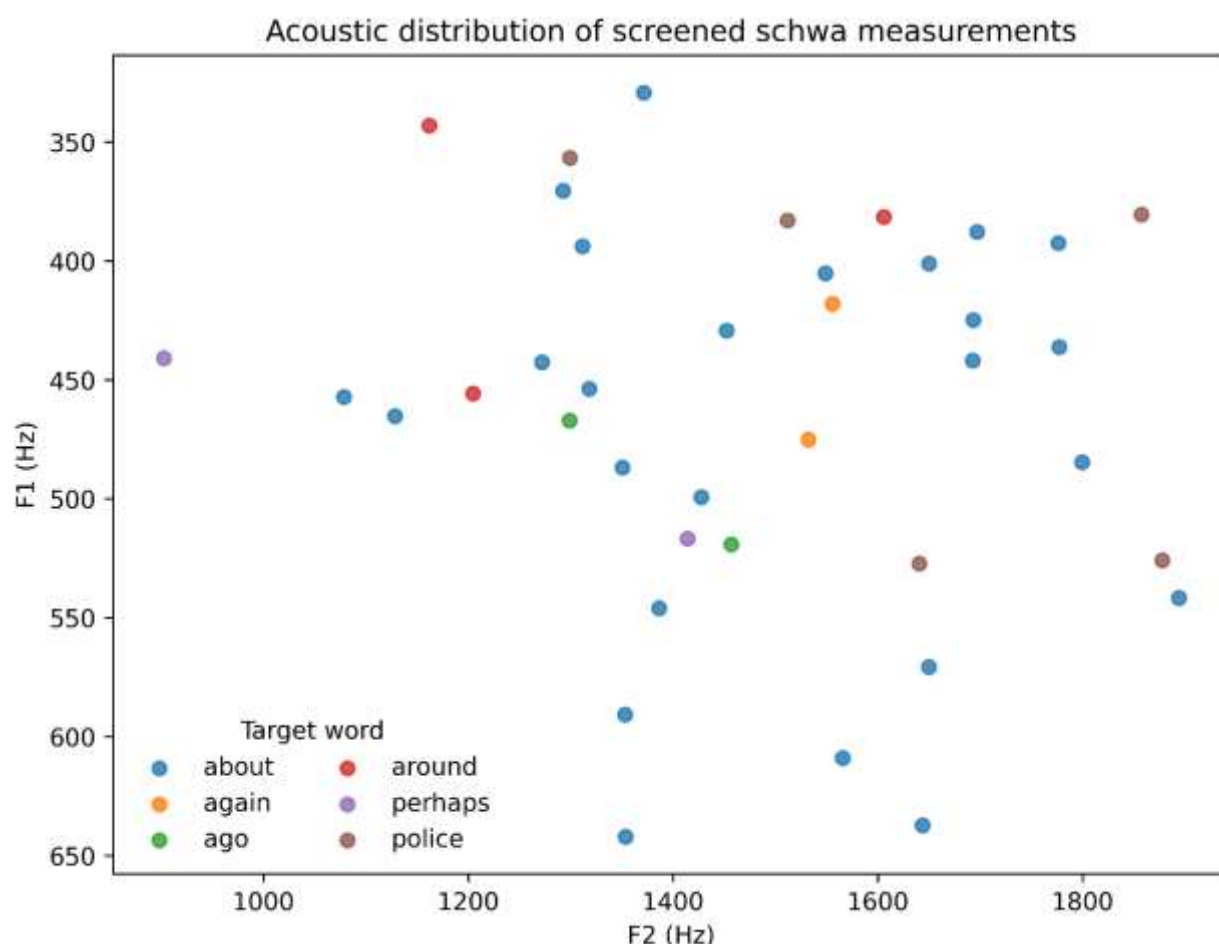


Figure 3. F1-F2 distribution of the screened schwa observations

Scatter plot showing the relationship between F1 and F2 for the 39 screened schwa observations, grouped by target lexical item.

The distribution is particularly informative for F2. The observed F2 range extends from 902.4 Hz to 1894.0 Hz, indicating appreciable spectral dispersion within the screened sample. Such dispersion is consistent with the possibility that the front-back dimension of schwa is sensitive to contextual influences.

4.4. Exploratory statistical comparisons

Because the lexical target groups were small and unbalanced, the Kruskal-Wallis test was treated as the primary exploratory statistical procedure. For F1, the Kruskal-Wallis test produced $H = 4.4933$ with $p = .4808$. For F2, the test produced $H = 5.8675$ with $p = .3193$, while the duration analysis yielded $H = 6.2092$ with $p = .2864$. None of these comparisons reached the conventional significance level of .05.

One-way ANOVA was additionally used as a supplementary comparison of group means. The corresponding p-values were .6061 for F1, .1505 for F2, and .2229 for duration. These results were consistent with the non-parametric analysis in that none of the observed lexical-group differences reached statistical significance.

The absence of statistically significant differences should not be interpreted as evidence that contextual variation in schwa is absent. Rather, the present sample does not provide sufficient evidence for strong systematic differences between the lexical target groups. The uneven group sizes and the confounding of lexical identity with phonetic environment further limit the generalizability of these exploratory statistical comparisons.

Table 3.

Exploratory statistical comparisons across lexical target groups

Measure	Kruskal-Wallis H	p-value	ANOVA F	p-value
F1	4.4933	.4808	0.7299	.6061
F2	5.8675	.3193	1.7513	.1505
Duration	6.2092	.2864	1.4798	.2229

Kruskal-Wallis tests were treated as the primary exploratory comparisons because the lexical groups were small and unbalanced. One-way ANOVA results are reported as supplementary comparisons.

The absence of statistically significant differences should not be interpreted as evidence that contextual variation in schwa does not exist. Rather, the result indicates that the present sample does not provide sufficient evidence for strong systematic differences between the lexical target groups included in this analysis. The sample size, uneven distribution of lexical items, and the fact that lexical identity is confounded with phonetic environment all limit the extent to which these exploratory tests can be generalized.

5. Discussion

The principal objective of this study was to examine whether schwa in unstressed syllables of British English can be adequately described as a single acoustically stable vowel. The results provide evidence that the measured realizations demonstrate substantial acoustic dispersion, particularly in F2 and duration. At the same time, the exploratory statistical comparisons did not reveal statistically significant differences among the lexical target groups represented in the sample.

The mean F1 of 462.32 Hz provides a general description of the vertical acoustic dimension of the analyzed schwa tokens. The standard deviation of 79.93 Hz demonstrates that individual observations do not converge on a single F1 value. Nevertheless, the absence of statistically significant lexical-group differences in F1 is compatible with the possibility that within the present sample, F1 appears less dispersed than F2, although the difference should be interpreted descriptively rather than as evidence of a statistically established difference in variability.

This observation can be considered in relation to Kondo's analysis of schwa. Kondo reported relatively limited F1 variation compared with the variation observed

in F2 and interpreted this pattern as evidence that schwa may be more constrained in the height dimension while being less specifically defined in the front-back dimension. The present descriptive results are compatible with this general interpretation, although the current sample is not large or experimentally balanced enough to establish the same theoretical conclusion independently.

The F2 results are particularly noteworthy. The mean F2 was 1482.06 Hz, while the standard deviation was 235.49 Hz and the observed range extended from 902.4 to 1894.0 Hz. The relatively broad distribution illustrates that schwa tokens may occupy different positions along the acoustic front-back dimension. This finding is consistent with the contextual sensitivity reported in previous research.

The relationship between schwa and its neighbouring consonants is important in interpreting this result. The target words in the present corpus occur in different segmental configurations. For example, *police* begins with a consonant followed by schwa, while *about*, *ago*, and *around* begin with schwa. Consequently, the articulatory transition into and out of the vowel differs between lexical items. Such differences can affect formant trajectories and therefore contribute to the observed acoustic dispersion.

The duration findings provide an additional perspective. The mean duration of 83.59 ms and the range from 25 to 145 ms indicate substantial temporal variability. This is consistent with the broader concept of vowel reduction, in which unstressed vowels are often characterized not only by reduced spectral differentiation but also by temporal compression.

However, duration should not be interpreted as a direct measure of stress alone. Speech rate, local prosodic structure, segmental context, and the position of the word in the utterance may all affect the temporal realization of a vowel. Therefore, the duration variation observed in the present corpus should be understood as evidence of phonetic variability rather than as a simple categorical distinction between stressed and unstressed vowels.

The statistical analysis provides an important qualification to the descriptive findings. Although the acoustic measurements show considerable dispersion, the differences among lexical target groups did not reach statistical significance for F1, F2, or duration. This apparent combination of broad within-sample variability and non-significant between-group differences suggests that the observed variation may not be explained simply by lexical identity.

One possible interpretation is that the relevant source of variability lies at a more fine-grained phonetic level. The acoustic realization of schwa may be influenced by the exact preceding and following segments, speech rate, prosodic position, and speaker-specific characteristics. Because the present sample contains naturally occurring corpus speech rather than a controlled laboratory experiment, these factors cannot be completely separated.

This limitation is also relevant to comparison with Bates's work. Bates investigated a much larger collection of vowel tokens and emphasized the context-dependent nature of vowel realization in connected speech. The present study similarly finds that schwa should not be regarded as an acoustically invariant segment, but the smaller corpus sample limits the strength of the statistical conclusions that can be drawn.

The findings therefore support a distinction between phonological stability and phonetic variability. At the phonological level, the target vowel can be consistently identified as schwa /ə/. At the phonetic level, however, its realization is variable. This distinction is important because a phonological transcription does not encode all of the acoustic information contained in the speech signal.

The present analysis also demonstrates the value of combining corpus transcription with acoustic analysis. Orthographic and phonological representations allow target vowels to be identified, but acoustic analysis reveals properties that are not represented in the transcription. Waveform and spectrographic analysis provide evidence about the temporal extent and spectral characteristics of the vowel and therefore make it possible to examine the relationship between reduced-vowel categories and their physical realization.

The study nevertheless has several limitations. First, the analyzed sample is relatively small after acoustic quality screening. Second, the lexical target groups are not balanced. Third, the naturally occurring corpus data contain contextual and speaker-related variation that cannot be fully controlled. Fourth, the transcript-level corpus material does not provide uniformly verified word-level acoustic boundaries for every potential schwa occurrence. For this reason, the quantitative analysis is intentionally restricted to the screened observations for which acoustic measurements were considered sufficiently reliable.

These limitations do not invalidate the descriptive results, but they determine how they should be interpreted. The present study should be understood as a corpus-based acoustic investigation rather than a fully controlled experimental study of all British English schwa realizations.

Future research could address these limitations by constructing a larger balanced dataset in which the same lexical items occur across multiple speakers and phonetic contexts. Word-level and phone-level forced alignment could also be used to establish more precise temporal boundaries. Such a dataset would make it possible to model the independent effects of preceding consonants, following consonants, stress environment, speech rate, and speaker identity.

6. Conclusion

This study investigated the acoustic realization of schwa in unstressed syllables of British English using authentic speech material from the ICE-GB corpus. The

analysis focused on three acoustic parameters-F1, F2, and duration-in order to examine both spectral and temporal properties of the reduced vowel.

Following acoustic quality screening, 39 observations were retained from an initial set of 59 candidate measurements. The resulting dataset produced a mean F1 of 462.32 Hz, a mean F2 of 1482.06 Hz, and a mean schwa duration of 83.59 ms. The acoustic measurements demonstrated noticeable variation, particularly in F2 and duration.

Exploratory statistical comparisons across the lexical target groups did not reveal statistically significant differences in F1, F2, or duration. Nevertheless, the observed dispersion of the acoustic measurements indicates that schwa should not be interpreted as an acoustically invariant vowel with a single fixed realization. Instead, its phonetic realization appears to occupy a range of acoustic configurations.

The findings are broadly consistent with previous research by Kondo and Bates, which emphasized the contextual nature of schwa and the influence of surrounding segments on its acoustic realization. The present study therefore supports a distinction between the stability of schwa as a phonological category and the variability of its phonetic realization.

In conclusion, schwa in British English can be regarded as a reduced vowel category whose acoustic properties are shaped by the conditions in which it occurs. F1, F2, and duration together provide a more informative description of this realization than a categorical phonological transcription alone. The results also demonstrate the usefulness of corpus-based acoustic analysis for examining the relationship between vowel reduction, coarticulation, and phonetic variation in British English.

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